

AGENT CHAMELEONS: MIGRATION AND MUTATION WITHIN AND BETWEEN REAL AND VIRTUAL SPACES

G.M.P. O'Hare¹ & B.R. Duffy²

¹Department of Computer Science, University College Dublin (UCD), Belfield, Dublin 4;

²Media Lab Europe (MLE), Sugar House Lane, Crane Street, Dublin 8

Gregory.OHare@ucd.ie; brd@media.mit.edu

Abstract

This paper introduces the concept of *Agent Chameleons* and investigates the motivation, desire and possibilities of agent migration and mutation within and between real and artificial spaces. Information spaces manifest themselves in many forms. Benefits exist where the agent/user is immersed and feels a sense of presence within such spaces. Agents often take on an embodied form. This form embodies the agent together with its associated behaviours and capabilities. The agent behaviour is inextricably mediated by a set of laws, the *agent physics laws*. This paper investigates the possibility of agents seamlessly migrating across traditional impervious inter-world boundaries and the associated possibility of agent forms mutating in order to empower itself. Such mutation may occur as the agent context changes. Context shifts can occur as the agent migrates from one world to another or indeed when environmental factors change within a given world.

1 Introduction

"If I had a world of my own, everything would be nonsense, nothing would be what it is, because everything would be what it isn't. And contrary wise, what it is it wouldn't be and what it wouldn't be it would."

Lewis Carroll, Alice in Wonderland

Increasingly we are witnessing a convergence between what were previously viewed as discrete information spaces. Historically the physical world was the first information space but has subsequently been joined by a rich array of virtual information spaces.

This paper seeks to investigate the integration of these information spaces by blurring the traditional boundaries between the Physical & the Virtual (information spaces). Ultimately we strive to support the opportunistic migration of the agent chameleon from the physical environs to that of the virtual and vice versa. The ultimate goal is seamless transition as the entity moves from one space to another.

It is our conjecture that the agent chameleon must have a sense of presence [Breazeal 2000] [Sas & O'Hare 2001] and thus be embodied within a given world. Indeed the form of an entity inextricably dictates or constrains its behaviour and capabilities within a particular environ-

ment. The optimum form is very much dependent upon its world [O'Hare 2000]. Judicious selection of appropriate forms or persona ought to empower the entity. In particular we view the mutation and evolution of agent forms as the ultimate animation of an expressive character, whereby the entire form may change rather than the mere change of limited components like the facial expression or character posture. To date this possibility has not been exploited nor delivered.

2 Objectives

The objectives of *Agent Chameleons* are as follows:

- 1) To investigate the choice and selection of embodiment forms;
- 2) To develop a mechanism whereby agent chameleons can migrate;
- 3) To investigate processes that support the mutation and evolution of agent forms;
- 4) To re-examine the concept of community and offer a redefinition based upon Collaborative Immersive Virtual Environments [O'Hare et al 2001]

3 The Vision

Within this research we seek to dismantle traditional world boundaries. We strive for a seamless migration from the physical to the virtual and the virtual to the physical. Synonymous with this migration is the obligation or possibility for *agent metamorphosis* whereby the entity changes representation such that its form is appropriate to the new *context*. The context is viewed as a tuple of task or activity and the new environment. Examples include:

- Agents adopting an avatar persona;
- Humans adopting a robotic avatar persona;
- Robots adopting a humanoid persona (HMD's)

The form of an entity inextricably dictates or constrains its behaviour and capabilities. The form is very much dependent upon its world. Appropriate forms or persona ought to empower the entity. In particular we will investigate two approaches.

- (1) Augmentation of the *virtual* with the *physical*
This will involve the depiction of photorealistic avatars representing real people in virtual spaces as typified by the Blue-c Project and the ETH's Real Humans in Virtual Worlds [Stadt 2000].
- (2) Augmentation of the *physical* with the *virtual*
Involving the use of VR Headsets enabling users to see virtual characters in real space. Influential examples include the Virtual Round Table developed at GMD [Broll et al 2000a, Broll et al 2000b], and the Interactive Video Environment(IVE) of MIT [Wren et al 96]

In supporting agent immersion and migration from one world to the next we envisage an *agent chameleon* that will evolve a unique individual personality through prolonged interaction with the user. Such a trait aims to ensure agent-person familiarisation over time and across platforms (dimensions/information spaces). This strong notion of personality and character addresses the inherent embodiment issues of agent mutation. The agent effectively embodies itself depending upon the required scenario, a concept completely new to the field of artificial intelligence and embodied systems.

4 Related Work

This work will develop influential research within the arena of collaborative and immersive environments. It builds upon seminal work conducted by the Collaborative Virtual Environment (CVE) community. Notable pioneering systems that incorporate agent-based techniques include DIVA-Distributed Intelligent Virtual Agent [Vosinakis et al 1999], MAVE-Multi-agent Architecture for Virtual Environments [Cobel & Harbison 1998], STEVE [Johnson & Rickel 1999], Trilogy [Norman & Jennings 2000], ECHOES [O'Hare et al 1999] [O'Hare et al 2000a] [O'Hare et al 2000b] [Pasquarelli et al 1999], ENTER [Guinan et al 2000].

The realisation of evolvable characters in virtual environments will draw inspiration from such work as Synthetic Characters at MIT-Media Laboratory [Blumberg 1996], and work on agents as synthetic characters [Badler et al 1993], [Cassell 1994], [Doyle & Hayes-Roth 1998], [Foner 1997], [Reilly 1996].

Specifically, the agent chameleons will draw upon work undertaken by the one of the authors in mobile agents [Hristova & O'Hare 2001a] [Hristova & O'Hare 2001b] [O'Ha 2000] [O'Ha2001] [O'Hare & Jennings 1996], the synthesis of real and virtual environments (VR-Workbench, [Duffy et al 1999], Social Robots [Duffy et al 2000] [O'Hare & Duffy 2002] [O'Hare et al 1999], and adaptive social interaction [Brezzeal 1998] [Brezzeal 2000].

5 Methodology

Existing research has investigated the development of social robotics, a mechanism that supports the opportunistic collaboration of teams of robots in the solution of joint goals [O'Hare & Duffy 2002],[Duffy 2000].

Within the context of this work a *Virtual Robotic Workbench* [Duffy et al 1999] has been designed and created which supports the articulation of robotic experiments, through the medium of the Internet. Key experimental descriptors were identified and instantiated. Such descriptors would permit the choice of the world within which the robots would be situated, the initial placement and number of robots, and the skill set and goal(s) associated with each robot. The Virtual Robotic Workbench serves as a visualisation metaphor depicting robotic avatars, in an accurate manner, reflecting the behaviour of the real world counterpart.

The Virtual Robotic Workbench served as the initial start point for this research and acts as a bootstrap in order to ensure the rapid delivery of proof-of-concept demonstrators. The intention in the first instance is to overlay this virtual world with *predesignated portals* or *black holes*, through which the world may be entered and exited. Thus entities migrating within a physical world could then be teleported into a virtual world and vice versa. The migration could result in an appropriate



Figure 1: A Physical World inhabited by Soccer Playing Robots

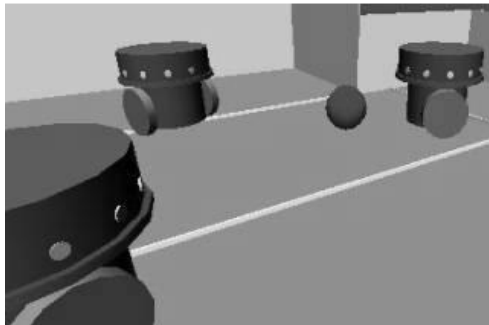


Figure 2: A Virtual World inhabited by Virtual Soccer Playing Robots

mutation of the entity thus manifesting itself differently within the new environment. A robotic avatar for example may take on the guise of a warrior in a hostile environment, whilst in a children's educational environment it may be cuddly and cute.

Two worlds are depicted in Figures 1 and 2, which respectively depict a physical and virtual representation of the same information content, namely soccer playing robots. We are currently developing physical and virtual worlds that are interconnected. Thus robots in the physical soccer scenario upon crossing the centre line of the

pitch move into the other half of the pitch that is virtual with virtual ball, players and goals.

The *agent* is thus considered as an autonomous, mobile and social entity in the classic multi-agent systems sense. Above and beyond this it is considered an *agent chameleon*. The agent has at any given instance a *persona* and associated with a given persona are a given set of capabilities. The migration and mutation of agents may thus be invoked in one of two manners, firstly by the agent itself through *proactive mutation/migration* or secondly, as a result of environmental events, *reactive mutation/migration*. Both proactive and reactive responses are determined by input parameters which originate internally and externally to the agent. The former comprise the personality attitudes (e.g. aggression, friendliness, moodiness) and mentalistic attitudes (e.g. Beliefs, Desires, Intentions(BDI)) while the latter are situational or environmental.

The agent chameleon is modelled on the idea of realising an *digital friend*. This research dismantles existing constraints whereby an agent is restricted to either a particular hardware or a software environment and aims to achieve a synthesis between both the physical and the virtual information spaces. It relies on wireless technologies to migrate between platforms (802.11/Bluetooth). This work draws on work undertaken by Keegan and O'Hare 2002] in the mobile agent research and extends this through the development of strong personality functionality and a tangible presence in multiple information spaces.

As mentioned in section 4, the role of a strong sense of personality and synthetic character play an important role in Human-Agent Interaction(HAI). Personality in this work is instrumental in influencing the mutation of the agent chameleon through information spaces. An example is the persistence of a particular unique quirky behaviour as an agent mutates from one form to another. The aim is to maintain a sense of personal intimacy with the agent notwithstanding its mutation.

The application domain is analogous to bringing one's pet for a walk (mobile agent on a PDA device) and from time to time unleashing it to run an errand (agent travels via wireless protocols to other devices, performs some task, and returns at some time later). Audio, visual, and motion behavioural responses will constitute the familiarisation mechanisms to facilitate consistency in personal relationships developed between the user and the agent as it mutates across information spaces.

One can similarly draw analogies between the “Tama-gochi” idea where a personal bond is developed between the user and the agent over time. This is extended greatly through the following innovative research initiatives:

- 1) The development of a strong sense of behavioural identity through personality and character traits exhibited by the agent to the user.
- 2) The mutation of forms: The agent is capable of migrating through virtual and physical information spaces through its selection of a “body” conducive to the task at hand based on its needs, desires, and options.

A richer interaction medium would thus be engendered between the user and the *collective information space*¹. Through the realisation of a personal relationship between the agent chameleon and the user, this project aims to achieve a more tangible sense of presence in the digital world. Traditional human-computer interaction (HCI) is generally a highly structured formal medium of “conversation”. This work seeks to extend from the keyboard and mouse paradigm to a notion of *personable computing* through the development of *agent friends* and to address the following crucial issues in HCI:

- 1) how to naturally entrain users to fully and comfortably take advantage of technology
- 2) how to compensate a loss of efficiency in the interaction process as the medium becomes less formal/structured (personalisation).

In parallel to the fusion of the physical and virtual spaces we also examine the fusing of the social space where characters may be virtual or real. Thus, a redefinition of the traditional community concept is necessitated [O’Hare & Byrne et al 2001], whereby new forms of *social inclusion* and *social norms* are accommodated. Further to this we will investigate *Social embodiment* and such issues: as robots delivering a form of telepresence for an associated human in a social space.

6 Conclusions

Within this paper we explore the blurring of the traditional information space boundaries, in particular the 4th dimension where the virtual is fused with the physical in an indistinguishable manner. Further to this we examine

¹ By Collective Information Space we refer to the Union of all spaces physical and virtual.

the decision making process that underpins the change of agent form and the potential for such processes as *agent cloning* and *agent evolution* where in a Darwinian sense through *socially situated learning* [Breazeal 2000] the agents may learn from their experience and evolve in the light of this. We postulate that the next form of evolution that must be addressed is the evolution of autonomous software entities.

Acknowledgements

This work was undertaken as part of the Agent Chameleons project a collaborative project undertaken between the Department of Computer Science, University College Dublin (UCD), Media Lab Europe (MLE), Dublin and Media Lab, MIT, Cambridge, USA. We gratefully acknowledge the financial support of the Higher Education Authority (HEA) Ireland.

References

- B. M Blumberg,. 1996. Old Tricks, New Dogs: Ethology and Interactive Creatures. Ph.D. Dissertation, MIT, 1996.
- C. Breazeal(Ferrell), and B. Scassellati, “Infant-like Social Interactions Between a Robot and a Human Caretaker”, *Special issue of Adaptive Behavior on Simulation Models of Social Agents*, 1998.
- C Breazeal, "Sociable Machines: Expressive Social Exchange Between Humans and Robots". Sc.D. dissertation, Department of Electrical Engineering and Computer Science, MIT, 2000.
- W Broll, E., Meier, T Schardt,: "The Mixed Reality Stage". *CAA Proceedings of the ACM SIGGRAPH 2000, 27th International Conference on Computer Graphics and Interactive Techniques*, (New Orleans, USA, July 23-28, 2000), p. 231, ACM, New York, 2000,
- W. Broll, E. Meier, T. Schardt, "The Virtual Round Table - A Collaborative Augmented Multi-User Environment". *Proc. of ACM CVE 2000: The 3rd Inter'l Conf. On Collaborative Virtual Environments*, E Churchill, M. Reddy (eds.), ACM, New York, pp39-46, 2000
- N. I. Badler; C.B. Phillips; and B.L. Webber,.. *Simulating Humans: Computer Graphics, Animation, and Control*., Oxford University Press, 1997.

- J. Cassell; C. Pelachaud, N. Badler; M. Steedman; B. Achorn; T. Becket, B. Douville, S. Prevost, and M. Stone, Animated conversation: rule-based generation of facial expression, gesture, & spoken intonation for multiple conversational agents. In *Proceedings of SIGGRAPH '94*, 1994.
- J. Cobel, K. Harbison, "MAVE: A multi-agent architecture for virtual environments", in *Proc 11th Int. Conf. on Industrial and Engineering Applications of artificial intelligence and Expert Systems*, LNAI, Vol.1415, Springer Verlag, 1998.
- B. R. Duffy, R. W. Collier, G. M. P. O'Hare, C. F. B. Rooney, , R. P. S O'Donoghue., Social Robotics: Reality and Virtuality in Agent-Based Robotics, In *Proc. Bar-Ilan Symposium on the Foundations of Artificial Intelligence: Bridging Theory and Practice, Ramat Gan, Israel*, 1999.
- B. R. Duffy, C. Garcia, C. F. B. Rooney, G. M. P. O'Hare, Sensor Fusion for Social Robotics *Proc. 31st International Symposium on Robotics (ISR2000)*, May 14-17, 2000, Palais des congrès, Montréal, Canada, 2000.
- P. Doyle, and B. Hayes-Roth, Agents in annotated worlds. In *Proceedings of the Second International Conference on Autonomous Agents*. Minneapolis, MN: ACM Press, 1998.
- B. R. Duffy,, The Social Robot, Ph.D Thesis Department of Computer Science, University College Dublin (UCD), Dublin, Ireland, 2000.
- L. Foner, Entertaining agents: A sociological case study. In *Proceedings of the First International Conference on Autonomous Agents*, 122-129. Marina del Rey, CA: ACM Press, 1997.
- T. Guinan, T., G. M. P.O'Hare, and N. Doikov, ENTER: The Personalisation and Contextualisation of 3-Dimensional Worlds, *Proc. 8th Euromicro Workshop on Parallel and Distributed Processing, EURO-PDP 2000*, pp 142-148, IEEE Computer Society Press, Jan. 19-21st, 2000, Rhodes, Greece, 2000.
- N. Hristova, & G. M. P. O'Hare, Ad-Me: A Context-Sensitive Advertising System, *Proc. Third International Conference on Information Integration and Web-based Applications and Services (iiWAS 2001)*, 10-12 Sept. 2001, Linz, Austria,
- N. Hristova, & G. M. P. O'Hare, Ad-me: Intelligent Context-Sensitive Advertising within a Mobile Tourist Guide,, *Proc 12th Irish AI and Cognitive Science Conference.*, 5-7th Sept, 2001, University of Maynooth, Ireland.
- L. Johnson, J. Rickel, "Virtual humans for team training in VR", *Proc. 9th World Conference on AI in Education*, pp578-585, July 1999.
- S. Keegan., S., G. M. P. O'Hare, "Easi-Shop: Enabling product description services and automated shopping using mobile agents with the Ericsson Bluetooth Development Kit", submitted to 17th ACM Symposium on applied computing (SAC2002), Madrid, Spain, March 10-14, 2002.
- T. J. Norman, N. R. Jennings, "Constructing a virtual training laboratory using intelligent agents", *Int Journal of Continuous Engineering and Life-Long Learning*, 2000.
- G. M .P. O'Hare, & B. R Duffy,. The Social Robot, Wiley Publishers, (In Preparation)
- G. M .P. O'Hare, & B. R Duffy, R. W. Collier, C. F. B. Rooney., R. P. S. O'Donoghue., Agent Factory: Towards Social Robots, *Proc. First International Workshop of Central and Eastern Europe on Multi - Agent Systems (CEEMAS'99)*, St.Petersburg, Russia, 1999.
- G. M. P. O'Hare, T. Delahunty, A. J. Murphy, and K. Sewell, ECHOES: A Collaborative Virtual Training Environment. *Proceedings of the Fifteenth Twente Workshop on Language Technology* May 19-21 1999 Enschede, The Netherlands, 1999.
- G. M. P. O'Hare, Agents, Mobility and Virtuality: A Necessary Synergy, In *Proceedings of International ICSC Symposium on Multi-Agents and Mobile Agents in Virtual Organizations and E-Commerce (MAMA'2000)*, December 11-13, 2000, Wollongong, ICSC Academic Press, ISBN 3-906454-24-X, 2000.
- G. M. P. O'Hare, Personalised and Contextualised Content Delivery for Mobile Users, In *Proc.of 1st International Conference on Universal Access in Human Computer Interaction UAHCI 2001*, August 5th-10th 2001, New Orleans, Louisiana, USA, Published as *Universal Access in HCI: Towards an Information Society for All* published by Lawrence Erlbaum Associates, Inc., 2001
- G. M. P. O'Hare, and N. R. Jennings, (Editors.), *Foundations of Distributed Artificial Intelligence*, Sixth Generation Computer Series, Wiley-Interscience Publishers, New York, ISBN 0-471-00675, 1996.
- R. P. O'Rafferty, M. J. O'Grady, G. M. P. O'Hare. A Rapidly Configurable Location-Aware Information System for an Exterior Environment. *Proc. International Symposium on Handheld and Ubiquitous*

Computing (HUC 99), September 27-29, 1999
Karlsruhe, Germany, 1999.

- G. M. P. O'Hare, C. Sas, C. & C. Byrne, C., Agent Mediation and Management of Virtual Communities: A Redefinition of the Traditional Community Concept, Symposium on Technology, Economic and Social Applications of Distributed Intelligence (TESADI'01, *In Proc of IEEE Int'l Conference on Systems Man and Cybernetics (SMC'01)*, Tucson Arizona, Oct 7-10th, 2001, IEEE Press, 2001.
- G. M. P. O'Hare, K. Sewell, A. Murphy, & T. Delahunty, ECHOES: An Immersive Training Experience. *In Proceedings of International Conference on Adaptive Hypermedia and Adaptive Web-based Systems (AH2000)*. Springer Verlag.
- G. M. P. O'Hare, K. Sewell, A. Murphy, & T. Delahunty, An Agent Based Approach to Managing Collaborative Work within both a Virtual Environment and Virtual Community. *In Proceedings of the Workshop on Intelligent Agents for Computer Supported Cooperative Work: Technologies & Risks. Fourth International Conference on Autonomous Agents*, Barcelona, Spain.
- A. Pasquarelli, F. de Stefani, G. M. P. O'Hare, & A. J. Murphy, ECHOES: EduCational Hypermedia On-line System, *Proceedings of IEEE MultiMedia Conference*, Firenze, Italy June 19th-21st 1999.
- W. S. Reilly, W. S. Believable Social and Emotional Agents. Ph.D. Dissertation, CMU, 1996.
- C. Sas, C., G. M. P. O'Hare, Defining and Measuring Presence in Non-Virtual Environments: An Experimental Study, *In Proc. 4th International Workshop Presence 2001*, May 21-23rd, Temple University, Philadelphia, PA, USA, 2001.
- O. G. Staadt, A. Kunz, M. Meier, M. H. Gross: The Blue-C.: Integrating Real Humans into a Networked Immersive Environment. *Proc. of ACM Collaborative Virtual Environments 2000*, pp. 201-202, ACM Press, 2000.
- S. Vosinakis, G. Anastassakis, T. Panayiotopoulos, "DIVA: Distributed Intelligent Virtual Agents", *Proc. VA99, Workshop on Intelligent Virtual Agents, at UK, VRSIG*, Sept 1999.
- C. R. Wren, F. Sparacino, et al. TR#372: Perceptive Spaces for Performance and Entertainment: Untethered Interaction using Computer Vision and Audition (*Submitted to Applied Artificial Intelligence (AAI) Journal*, March 1996.